

THE INSTITUTE OF PHYSICS

47 BELGRAVE SQUARE, LONDON, S.W. 1.

BULLETIN



VOL. VI, No. 10

OCTOBER, 1955

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*The Bulletin is not intended for general circulation :
your copy should not therefore be passed to a library.*

APPOINTMENTS VACANT

The inclusion of particulars of a vacancy must not be taken to imply that the Institute necessarily approves of the terms offered or that might be offered. Candidates should satisfy themselves that these are satisfactory, and they may always refer to the Institute for advice.

British Petroleum Co. Ltd. has vacancies for geophysicists on its exploration staff. Candidates should have an honours degree in physics with subsidiary mathematics and/or geology, but candidates with a general degree will be considered. The work involves delineation of underground rock structure by seismic, gravitational and magnetic techniques and offers considerable scope for men with initiative who are prepared to travel and to work abroad. Normal leave is four months after two years' foreign service.

When conditions permit, facilities are afforded for married men to have their families with them on foreign tours.

Basic salary is commensurate with age and experience, commencing at £870 for young, inexperienced graduates. Appropriate allowances are paid whilst on foreign service. Generous pension scheme.

Applications quoting F.107, should be addressed to Box 1442, c/o 191 Gresham House, E.C.2.

British Petroleum Company Limited invites applications from young Graduates with a degree in Engineering, Physics, Mathematics or Natural Philosophy, to be trained as Petroleum Engineers. Training will last for approximately 2 years and will take place partly in the United Kingdom and partly overseas. On successful completion of the training, men will be posted as **Resident Petroleum Engineers** to exploration areas overseas. Age preferably not over 26, National Service obligations must have been fulfilled. Write stating age and full details of qualifications and experience quoting H.2089 to Box 7649, c/o 191 Gresham House, E.C.2.

Graduates

of proven ability in their present fields, and who would be interested to consider a career in electronics, are invited to discuss the careers that would be open to them with Decca Radar Limited. The Company is expanding rapidly both in size and scope of interests, and the opportunity is extended to first class men to train at a salary dictated to some extent by their standing in their present field for command positions in the research laboratories of the Company. A pension scheme is in operation. British Nationality is essential. Please write, giving full personal details, to Decca Radar Ltd., 2 Tolworth Rise, Surbiton, Surrey, quoting reference RLA.104.

The development of techniques and instruments for spectroscopic methods of analysis offers interesting and progressive employment to graduate physicists and engineers wishing to enter the scientific instrument industry. Applications for a post in N.W. London should be made to the Personnel Officer, **Hilger and Watts Ltd., Hilger Division**, 98 St. Pancras Way, N.W.1.

British Thomson-Houston Company Ltd., invites applications from science graduates for research on crystallography; previous experience in this field is not essential, but would be an advantage. Apply, quoting reference IAJ(2) and stating age, qualifications and experience to the Director of Research, **British Thomson-Houston Company Ltd.**, Rugby.

PHYSICISTS

Simon-Carves Ltd.

require physicists for research work in a number of fields—fluidization, flame combustion, electro-precipitation, small particle behaviour, reaction kinetics, applied thermodynamics and pneumatic techniques.

Candidates should be university graduates or have professional qualifications of Associate Membership standard.

Salaries will be in the range £750-£1,250, depending on experience. The posts are at Stockport. Working conditions are excellent; scope is good; a pension scheme is in operation. Please send brief relevant applications (quoting Ref. BN 45) to Staff and Training Division, **Simon-Carves Ltd.**, Cheadle Heath, Stockport.

There are vacancies in the Company's Research Laboratories at Rugby in a group engaged on the development of semi-conductor devices and their associated circuitry. Requirements are for:—

- (i) **Qualified Physicists or Electrical Engineers as Senior Development Engineers.**
- (ii) **An Engineer** to take charge of and organize small scale experimental production in the Research Laboratory, of small electrical devices.
- (iii) **Qualified Electronic Circuit Engineers** for the exploratory development of transistor circuits.
- (iv) **Laboratory Assistants** with Ordinary National Certificate in physics, electrical engineering or chemistry. There will be staff appointments for suitable applicants.

Applicants are invited to write to the Director of Research, **British Thomson-Houston Company Ltd.**, Rugby, quoting reference HR.

Senior Lighting Development Engineer wanted for factory in the North Midlands. Age preferably between 30 and 35. Applicants should possess a degree in physics or engineering, or Higher National Certificate, and should be experienced in the design and development of lighting equipment. Good salary and excellent prospects. When replying please give full details of age, education, technical experience and salary required. Our own staff have been informed of this vacancy. Apply Box 85, The Institute of Physics, 47, Belgrave Square, London, S.W.1.

Imperial Chemical Industries Limited Dyestuffs Division, invites applications from **physicists** for a position in the Physics Section of the Research Department. The work, which is concerned with the development of physical techniques applicable to problems arising in organic chemical research, provides a wide variety of topics for investigation and offers scope for scientific initiative. The position also offers good financial prospects to suitable applicants, who should possess a good honours degree in physics, be under 30 years of age and preferably have had some research experience. Please write in detail to the Staff Manager, **I.C.I. Ltd.**, Hexagon House, Blackley, Manchester, 9.

Semi-conductor Research

There are vacancies in the company's research laboratory at Rugby for **Physicists** to work in a small but expanding group on the development of semi-conducting materials. Graduate physicists are required to devise methods for producing the material in perfect crystalline form and for assessing its characteristics: others qualified at least to Higher National Certificate standard are wanted as **Laboratory Technicians** to assist in the above work.

Applicants are invited to write to the Director of Research, **British Thomson-Houston Company Ltd.**, Rugby, quoting reference W1.

There is a vacancy for a **Nucleonic Instrument Engineer** in the Atomic Energy Department of **The General Electric Company Limited**.

Applicants should have a degree in electrical engineering or physics and several years' experience in electronic engineering. The appointment is a senior one, carrying a good salary with opportunities for advancement. Application should be made to Personnel Manager, Fraser & Chalmers Engineering Works, Erith, Kent.

Imperial Chemical Industries Limited
Billingham Division
has vacancies for
Physicists
and
Electrical Engineers

preferably with experience in electronics for Assistant Technical Officer posts in their Engineering Research Laboratories.

Candidates should be not more than 30 years of age and should have at least an Inter B.Sc. qualification or the equivalent. A pass degree would be advantageous.

Attractive salaries are offered, dependent upon qualifications and experience.

Financial assistance towards removal expenses available for married men.

Excellent conditions of employment including Staff Pension Fund, Profit Sharing Scheme, etc.

Write, without commitment, to the Staff Manager, Imperial Chemical Industries Limited, Billingham Division, Billingham, Co. Durham, quoting reference H.6.

Manchester
College of Technology
(Faculty of Technology in the University of Manchester)
Appointment of
Demonstrator in Metallurgy

The Governing Body invites applications for a Demonstratorship in Metallurgy in the College of Technology, with the title and status of Demonstrator in the University of Manchester.

Candidates should be honours graduates in Metallurgy, Physics or Chemistry and will be expected to undertake research work in Metallurgy, which may lead to a higher degree.

The appointment is subject to renewal annually and will carry a salary of £425 per annum in the first year and £450 per annum thereafter. Superannuation under the F.S.S.U. and family allowances.

Application forms may be obtained from the Registrar, College of Technology, Manchester 1. The last day for the receipt of applications is October 31, 1955.

B. V. Bowden,
Principal of the College.

Physicist or Physical Chemist wanted for development work on laboratory apparatus. Ample opportunity for graduate with lively mind interested in the design and construction of instruments and equipment. Starting salary £650-£850, according to qualifications and background. Five day week and pension scheme. Apply in writing to Technical Adviser, A. Gallenkamp & Company Ltd., 17-29 Sun Street, London, E.C.2.

United Steel Companies invite applications from young science graduates keen to do laboratory and plant research on steelmaking furnaces. Reply, Assistant Director of Research, Swinden Laboratories, Moorgate, Rotherham.

Surrey Education Committee—**Redhill Technical College**, Redstone Hill, Redhill. Qualified **Laboratory Steward** required to be responsible for apparatus, including repairs, in Physics, Mechanics and Engineering Laboratories. Suitable qualifications are G.C.E. City and Guilds or Laboratory Technician's Certificate. Practical experience essential. Salary in accordance with Miscellaneous Grade III, £420 x £15 to £465 x £20 to £485. Applications should be submitted to the Principal as soon as possible.

University of Southampton. Department of Physics. Applications are invited for a **Research Studentship** value £450 per annum and fees, tenable for two years with possible renewal for a third year, for research work on the physical properties of liquid metals and leading to a higher degree. Good honours degree in physics or metallurgy required. Applications to Professor of Physics as soon as possible.

Spectroscopist, preferably experienced in infra-red work, required for editorial work on the Documentation of Molecular Spectroscopy punched card system. Salary according to qualifications and experience. Applicants, male or female, are invited to apply, giving full details of qualifications and experience to the Secretary, **Butterworths Scientific Publications**, 88 Kingway, London, W.C.2.

Physicist (Grade IV) required to work on problems associated with the use of a fission product radiation source for radiotherapy. The appointment will be held in the Physics Department, **Institute of Cancer Research**, The Royal Cancer Hospital, Fulham Road, London, S.W.3, but most of the successful applicant's time will be spent with a 1,000 curie caesium unit at Sutton, Surrey. Salary in the range £500-£650 with prospects for advancement. Please send details of educational and other qualifications to the House Governor, Royal Marsden Hospital, Fulham Road, S.W.3.

Scientists qualified in physics, electrical or mechanical engineering are required by the **British Scientific Instrument Research Association** in the laboratories at Chislehurst, Kent. Vacancies exist for those recently graduated and for others with some industrial or research experience. Age up to 30.

E.M.I. Engineering Development Ltd. Senior Engineer/Physicist

An attractive vacancy exists at this Company's Feltham laboratories for a Senior Engineer/Physicist to work on a number of theoretical problems in the G.W. field. The man we are looking for will be qualified and will have had some related experience. His main responsibility will be to devise series of critical laboratory and field experiments in connection with weapon development. An attractive salary will be offered to the successful applicant for this pensionable post, and the prospects in this active and expanding Company are excellent. Please send your first reply to Personnel Dept. (ED/238), E.M.I. Eng. Dev. Ltd., Blyth Road, Hayes, Middlesex.

British Petroleum Company Limited requires a qualified **Mechanical Engineer** for research into the design and production of new instruments for geophysical exploration. Applicants should have, in addition to sound background of the fundamentals of their subject, practical knowledge of the uses and limitations of engineering materials and methods as applied to the design of precision instruments, an understanding of the principles of kinematic design and some experience in research. A first-class man is required for this interesting project and an appropriate salary will be paid. The vacancy is in the Company's Research Station, which, for the time being, is situated in Nottinghamshire. Good Pension Scheme. Write, stating age and giving full details, quoting H.3330A, to Box 8032, c/o 191 Gresham House, E.C.2.

The British Iron and Steel Research Association

Physical Metallurgist required by the above Association to work in a Research Group concerned with measurements of fundamental properties of iron and steel, e.g. diffusion and the effects of small amounts of impurities. A university degree or equivalent qualification is essential. Some postgraduate research experience or industrial experience would be an advantage but is not essential. Results of the work would be suitable for submission for a higher degree. Applicants should preferably be within the age range 22-27 for which the salary would be within the range £550-£800 p.a. Consideration might be given to exceptional applicants outside these ranges. The post is superannuated under F.S.S.U., and the location of work is Sheffield. Written applications only quoting "M.G.I." to Personnel Officer, B.I.S.R.A., 11 Park Lane, London, W.1.

Research Grant—Young Science Graduates with a leaning towards physics will be considered for an opportunity involving three years' research at a university working for a Ph.D. degree. The work will be of a fundamental nature concerning the surface properties of high polymers and will be carried out under the direction of the university with all that this implies in the way of freedom to publish. The Company will be interested in the progress of the work, but there are no restrictions or ties of any kind. Candidates should possess a good honours degree and should be able to produce a recommendation from the Head of their own university department indicating suitability for continued research in the broad field described; preference may be given to those who have completed National Service. Please write in the first instance, giving brief information as to previous experience and interests, to the Personnel Manager, **British Nylon Spinners Ltd.**, Pontypool, Mon.

Applications are invited from Graduate Physicists for a post in the research laboratories of the **Cement and Concrete Association**. There is scope for interesting and varied work on problems of fundamental and applied research concerning the utilization of Portland cement.

A salary in the range £500-£1,000 is envisaged.

Candidates should apply to the Controller, C.C.A., Wexham Springs, Stoke Poges, Bucks.

Imperial College of Science and Technology London, S.W.7.

Applications are invited for **Junior Research Fellowship** in Instrument Technology Section of Physics Department. Applicants must have a physics degree and will be engaged in Photo-electronic research with facilities for attaining a higher degree. Salary £650 p.a. with F.S.S.U.

Applications with full particulars and names of two referees to Professor of Instrument Technology by October 1.

Birkbeck College (University of London). **Electronics engineer or physicist** required for the Computation Laboratory to work on problems of Character Recognition in connection with Mechanical Translation. Applicants should have recognized professional qualifications in electronics, and an interest in computing machines. The salary will be in the range of £600-£750 and the appointment will be tenable for three years. Further particulars should be obtained from the Secretary, Birkbeck College, Malet Street, London, W.C.1. Final date for applications October 29, 1955.

Aluminium Laboratories Limited, Banbury, require a number of **graduates and technicians** to work on the following problems:—

Metallurgical problems concerned with the continuous casting of aluminium.

Development of new alloys including studies of diffusion, constitution, the properties of intermetallic phases and the influence of these phases on the properties of the aluminium matrix.

Problems of physical metallurgy and in particular recrystallization.

Chemical physical problems such as the measurement of particle size surface tension and viscosity and the properties of surface films.

The development of non-destructive testing methods and in particular the study of the effect of variations in the constitution and structure of aluminium alloys on their physical properties.

The application of the theory of thermal transfer.

The study of the recrystallization of aluminium alloys by means of measuring changes in their damping capacity at elevated temperatures. Electrochemical problems relating to metal finishing.

The study of aluminium paste pigment.

Chemical problems concerned with metal-working lubricants and with the development of analytical methods.

The work is interesting and progressive, and provides unusual opportunities for men with initiative and enthusiasm to perform original research, which may be suitable for publication. The laboratories are situated in pleasant country surroundings and have recently been extended. The salaries will be attractive and in accordance with age and experience. A pension scheme is in operation. Applications should be addressed to The Director of Research, Aluminium Laboratories Limited, Banbury, Oxon.

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THE INSTITUTE OF PHYSICS

Vol. VI, No. 10

BULLETIN

OCTOBER, 1955

NOTICES TO MEMBERS

The British Nuclear Energy Conference

There are a few tickets still available to members of the Institute for the Inaugural Meeting of the British Nuclear Energy Conference to be held on Wednesday, November 30, at the Institution of Civil Engineers from 2.15 p.m. to 8.15 p.m. These tickets are for the personal use of members. A full record of the Proceedings of the meeting will be included in the first issue of the *Journal* of the British Nuclear Energy Conference which will be published in January, 1956. The retail price of this *Journal* is £3 0s. 0d. for the annual volume of four issues. Members of the five professional bodies that constitute the Conference, of which The Institute of Physics is one, may subscribe to the *Journal* at 30s. annually; a subscription form for 1956 is enclosed with this *Bulletin*.

Dates of Board and Committee Meetings

It may be helpful to members intending to apply for transfer to another grade of membership or to those asked to sign forms of application, to know the dates of the meetings of the Membership Committee and the Board. The dates fixed for the current session are:—

<i>Membership Committee</i>	<i>Board</i>
1955	1955
Thursday, September 29	Tuesday, October 4
Thursday, October 27	Tuesday, November 15
Thursday, December 29	1956
1956	Tuesday, January 17
Thursday, February 23	Tuesday, March 20
Thursday, April 26	Tuesday, May 15
Thursday, June 28	Tuesday, July 17
Thursday, September 27	

To ensure the minimum delay in consideration, applications for Fellowship and Associateship should be received not less than four weeks before a meeting of the Membership Committee; applications for Graduateship need to be received two weeks in advance, but those

for admission as Students or Subscribers can be considered if received two days before the Committee meets. Consideration of applications for corporate membership is often deferred because information has not been received from referees.

The Membership Committee reports to the following meeting of the Board and formal notification is usually received by candidates two or three days after the Board meeting.

Canadian Association of Physicists

The following letter has been received in reply to a cable from the President to the Canadian Association of Physicists on the occasion of the Association's Tenth Annual Congress.

Sir John D. Cockcroft,
President,
The Institute of Physics,
London, England.

Faculté des Sciences,
Blvd. de l'Entente,
Québec, Qué., Canada.
August 6, 1955.

Dear Sir,

I wish to express in the most heartfelt way possible, the sentiments of appreciation of the members of the Association for the delicacy and courtesy of the Best Wishes cabled on the occasion of our Tenth Annual Congress, held at Toronto last June.

Our formative years—still passing—have been considerably influenced by the experiences and example of many of the world's great Learned Societies. To your Institute we are pleased to extend our sincere gratitude and deep respect.

Very truly yours,
(Signed) Larkin Kerwin,
Past President.

Consultants for Fire Tests

The Joint Fire Research Organization of the Department of Scientific and Industrial Research and Fire Offices' Committee, would welcome the names of members of the Institute willing to act as consultants to carry out fire tests on manufacturers' products. The tests particularly are B.S.476 Combustibility Test and a flammability test described in B.S.476 Pt. II. Any members who may be interested can obtain details from Mr. D. I. Lawson, F.Inst.P., Assistant Director, Fire Research Station, Boreham Wood, Herts.

Display of Institute Publications

Some London members may have seen a special display of Institute publications that was on show during the summer in the Book Department of Harrods Ltd. A photograph of the display



is reproduced above. The Institute much appreciates the enterprise of Messrs. Harrods Ltd. in arranging this.

Report on the availability of places for physics students

The report on the availability of places for physics students, with the comments upon it, published in the September *Bulletin* is now available as a reprint. Members who would like to have copies, either for their own use or for distribution to others who would be interested, may obtain them free of charge on application to the Deputy Secretary.

Length of Papers for Publication

The Editor of the Institute's scientific journals believes that the view is held in some laboratories that papers exceeding 3,000 words cannot be considered for publication by the Institute in either the *British Journal of Applied Physics* or the *Journal of Scientific Instruments*. This is not so. Indeed, papers of nearly double this length have recently been published. To be acceptable, however, papers must be as concise as clarity allows.

**OFFICERS, MEMBERS OF THE BOARD AND OF BRANCH
AND GROUP COMMITTEES
1955-1956**

The new Board took office on October 1 and is composed of the following Fellows :

PRESIDENT

Sir John Cockcroft

IMMEDIATE PAST PRESIDENTS

Prof. W. E. Curtis

Dr. C. Sykes

VICE-PRESIDENTS

Mr. O. W. Humphreys

Prof. F. A. Vick

Mr. G. R. Noakes

Dr. W. H. Taylor

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Dr. S. Whitehead

HONORARY SECRETARY

Dr. B. P. Dudding

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Dr. P. S. H. Henry

Dr. M. R. Hopkins

Dr. J. M. A. Lenihan

Dr. K. A. G. Mendelssohn

Mr. A. T. Pickles

Mr. H. P. Rooksby

Dr. J. Taylor

CHAIRMEN OF BRANCHES IN GREAT BRITAIN

Liverpool and North Wales Branch : Prof. E. A. Owen

London and Home Counties Branch : Dr. J. S. Forrest

Manchester and District Branch : Dr. R. W. Sillars

Midland Branch : Dr. W. Betteridge

North-Eastern Branch : Prof. W. E. Curtis

Scottish Branch : Dr. J. M. A. Lenihan

South Wales Branch : Mr. R. G. Wood

Yorkshire Branch : Prof. E. C. Stoner

NOMINATED BY THE PHYSICAL SOCIETY

Dr. H. H. Hopkins

Mr. A. J. Philpot

The Officers and Members of Committees of the Institute's Branches and specialist Groups at the beginning of the session are :—

LIVERPOOL AND NORTH WALES BRANCH

Chairman : Prof. E. A. Owen.

Honorary Secretary : Prof. J. D. Craggs.

Committee : Prof. E. R. Andrew, Mr. A. Ashmore, Prof. K. F. Bowden, Mr. J. W. Broadhurst, Mr. G. E. Buckley, Mr. F. I. Hurley, Mr. J. W. Jones, Prof. J. H. Meek, Mr. R. J. Taylor, Mr. H. Tunley.

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Honorary Secretary : Mr. B. S. Cooper.

Committee : Dr. G. L. J. Bailey, Miss F. W. Black, Dr. V. E. Cosslett, Dr. D. H. Follett, Dr. R. Jackson, Mr. T. Somerville, Prof. A. M. Taylor.

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Honorary Secretary : Dr. D. G. Drummond.

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Honorary Secretary : Mr. T. H. O'Beirne.

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Committee : Mr. J. R. Atkinson, Dr. A. R. Boyle, Mr. A. L. Chilcot, Dr. C. B. Childs, Mr. D. McGill, Dr. G. Morris, Mr. J. W. Sharpe.

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Honorary Secretary : Dr. M. R. Hopkins.

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Committee : Dr. A. B. D. Cassie, Dr. J. Goodyear, Dr. M. McCaig, Mr. H. S. Peiser, Mr. W. C. Potts, Dr. D. L. Smare, Prof. P. W. Sucksmith.

EDUCATION GROUP

Chairman : Dr. J. Topping.

Honorary Secretary : Mr. F. Y. Poynton.

Committee : Miss T. J. Dillon, Dr. M. R. Hopkins, Dr. L. A. W. E. Kemp, Mr. E. W. L. Leavey, Dr. N. Pentland, Miss M. A. Richmond, Dr. J. H. Sanders, Dr. E. G. Stanford, Mr. E. W. Tapper, Mr. T. H. Tyler, Mr. W. Somerville Vernon, Prof. F. A. Vick, Mr. G. W. Warren, Mr. J. Yarwood.

ELECTRONICS GROUP

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ELECTRON MICROSCOPY GROUP

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Honorary Secretary : Dr. C. E. Challice.

Committee : Mr. A. W. Agar, Dr. S. Eaves, Mr. H. W. Emerton, Dr. J. W. Menter, Mr. H. L. Nixon, Dr. J. B. Le Poole.

INDUSTRIAL SPECTROSCOPY GROUP

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Honorary Secretary : Mr. J. R. Stansfield.

Committee : Dr. G. H. Beaven, Mr. K. M. Bills, Mr. L. Brealey, Mr. F. W. Garton, Dr. A. H. Gillieson, Dr. A. C. Menzies, Mr. S. Muir, Mr. W. Ramsden.

NON-DESTRUCTIVE TESTING GROUP

Chairman : Dr. J. Thewlis.

Honorary Secretary : Mr. R. S. Sharpe.

Committee : Prof. C. B. Allsopp, Mr. B. R. Byrne, Mr. E. G. Grimwade, Mr. R. Halmshaw, Dr. R. H. Herz, Mr. R. Meakin, Prof. J. S. Rankin, Mr. H. P. Rooksby, Mr. W. E. Schall, Dr. E. G. Stanford, Dr. R. W. B. Stephens.

STRESS ANALYSIS GROUP

Chairman : Mr. E. K. Frankl.

Honorary Secretary : Mr. B. Sugarman.

Committee : Mr. L. F. Atkinson, Miss N. Clutterbuck, Mr. H. Fessler, Mr. V. M. Hickson, Mr. T. Leach, Mr. W. A. Ray, Mr. C. Snell, Mr. H. Spooner.

X-RAY ANALYSIS GROUP

Chairman : Mr. H. P. Rooksby.

Honorary Secretary : Dr. U. W. Arndt.

Committee : Dr. K. W. Andrews, Dr. G. E. Bacon, Sir Lawrence Bragg, Dr. C. H. Carlisle, Dr. W. Cochran, Prof. E. G. Cox, Dr. R. L. Gordon, Dr. P. B. Hirsch, Dr. E. G. Steward, Mr. E. J. W. Whittaker.

CORRESPONDENCE

In his recent address to the Education Group*, Dr. R. S. Silver stressed the unique position occupied by thermodynamics, remarking that it formed the bridge between the sciences and the arts. Whilst in cordial agreement with this view, I should like to go one step further and to suggest that thermodynamics is the only branch of physics capable of being of any avail in that most difficult of disciplines, namely aesthetic theory. Two preliminary points are necessary, (1) that aesthetics is struggling valiantly to become a science, conformable to a proper methodology, and (2) it will only have a chance of succeeding if helped by some experimental philosophy of great delicacy and, in the main, independent of a mechanism. Both these needs are provided by thermodynamics and, as far as we know, by no other branch of natural knowledge.

Next, the development of aesthetic sense manifestly implies the recognition of visual *gestalten*, or organized wholes, the condition for the existence of which (as the present writer has endeavoured to show elsewhere) is a minimal free-energy as a function of organization, or balance of form. This concept is, algebraically, close to Willard Gibbs's thermodynamic potential, and statistically to entropy, because one is dealing with an "extremum." Again, the emergence of a work of art has been demonstrated to resemble in form Le Chatelier's principle coupled with a process akin to the metastable and labile states. All these are, at root, thermodynamical. Quantitative results can scarcely be expected: qualitative signs of an end-state (or stationary state) have however appeared, including (obviously) the hint of a teleological principle, linking them to directional biophysics and general system theory.

Finally, the axiomatic thermodynamics of Carathéodory are not excluded, because a place has been found for Pfaff's equation in the theoretical treatment of ordered form.

In all these examples, it is not claimed for a moment that thermodynamics can supply the answers to aesthetic problems: what that sublime science can do however is to orientate thought towards a stricter and more satisfying conception of beauty, and thus to help aesthetics to assume, one day, its full stature.

F. I. G. RAWLINS

The National Gallery,
Trafalgar Square,
London, W.C.2.

*The Teaching of Thermodynamics, *Bulletin*, August 1955, p. 193. *

It is refreshing to find the columns of the *Bulletin* open to both orthodox and unorthodox opinion ; even if one disagrees with the views expressed, the mere effort of finding why is always rewarding. But it is wrong for contributors to support their views by intemperate expressions, as I think that Dr. Silver has done in his contribution published in your August issue.

As I understand him, he would have us remove the calorie from physics. The unit rise of temperature would, I presume, be that produced by the absorption of one erg of energy in one gram of water. Surely, the present system of heat units and mechanical units, connected by the "intrusive and quite unnecessary symbol 'J'" has survived simply because physicists have found that this presentation is adequate and reasonable. Thermodynamics may be badly taught and badly appreciated, but in my experience the connection between heat and work is not the stumbling block.

But my main objection to Dr. Silver's article is to his expression "the absurd emphasis on experimentation and laboratory skill." As a member of a department whose main aim is to foster these abilities, I can assure Dr. Silver that they are extremely rare, and certainly cannot be taught in the way that the skills of the craftsman can be taught. I would say that the student who can design, carry out, check and write a coherent account of an experiment has received as good an education as he who can produce an analytical solution to a problem, or quote from the Odes of Horace !

Certainly, the country in which Joule, Faraday and Rutherford have worked has no need to sneer at experimental physics.

H. LIPSON

College of Technology,
Sackville Street,
Manchester 1.

I am sorry that Prof. Lipson thinks I have used "intemperate expressions." I would be grateful if Prof. Lipson would concede that many statements which can be made verbally in opening a discussion are desirably provocative, and also that the intonations and implications in manner of speaking on such occasions can make quite acceptable a wording which may appear rather outrageous when set down in cold print. I am glad to have the opportunity presented by Prof. Lipson's letter of assuring him and others, who may only have read my statement, that it was not delivered in an intemperate manner. My intention at least was to chide by gentle exaggeration, which is surely permissible on such occasions.

However, I was quite serious about the basic tenor of my remarks, to the effect that thermodynamics needs more developed teaching

than it has yet received from the average teacher, and that there is at present a trend in physics which shows too great emphasis on experimentation and laboratory skill, at least so far as the needs of an industrial physicist are concerned. At no point, however, did I, or would I, "sneer" at experimental physics as Prof. Lipson suggests, even though I do not belong, in his phrase, to "the country in which Joule, Faraday and Rutherford have worked" but to that of Maxwell.

It is to some extent a matter of definition, and I am rather amused at the three names which Prof. Lipson quotes as examples of experimental physics, namely, Joule, Faraday and Rutherford. These are all examples of men whose experimental work was associated with, and indeed was the focus of, strong theoretical conceptualizing. It was this activity of theory which made their work experimental physics. Without it, it would have been mere experimentation.

Prof. Lipson may care to note that I personally would regard analytical skills in mathematics as on the same level as technical skills in experimentation. Neither separately nor together can these two techniques make physics, and Faraday and Joule at least were great physicists without analytical skills. Once again, it is strength of theoretical concept which alone can make physics, either out of experimentation or mathematical analysis, or both. And it is therefore on clarity of theoretical concept that teaching emphasis should rest.

In regard to Prof. Lipson's minor point, I do not suggest that we need alter the system of heat units and mechanical units at all. What is necessary, however, is to realize that they all have the same ultimate dimensions, and that the equivalent factor be regarded as non dimensional, and as performing the same functions as, for example, the factors which connect miles per hour to feet per second, or centimetres per second. So long as J is thought of as something other than this it is intrusive, unnecessary and confusing.

R. S. SILVER

John Brown Land Boilers Ltd.,
Clydebank.

THE GRADUATESHIP EXAMINATION, 1955

The Institute's Graduateship Examination was held on June 20-23. Written papers were taken in London (the Institute's House), Birmingham (College of Technology), Salford (Royal Technical College), Paisley (Technical College) and a practical examination was held at The Polytechnic, Regent Street.

Fifty-four candidates sat the examination and the following 11 candidates satisfied the Examiners :

Bowen, P. H.	(Harwell, Berks.)
Catchpole, W. A.	(Sidcup, Kent)
Ford, D. R. G.	(Teddington, Middlesex)
Johnston, J. M.	(Inchinnan, Renfrewshire)
Jowitt, D.	(Oxford)
Joy, A. R.	(Romford)
Metcalf, C. S.	(London)
Rowan, D.	(Glasgow)
Tillen, R. J.	(Reading)
Tipping, F. R.	(Ellesmere Port, Cheshire)
Watts, J.	(Caterham, Surrey)

The successful candidates are deemed to comply with the academic requirements of the regulations governing election to Graduateship and corporate membership of the Institute.

The great majority of candidates taking the examination already held a qualification entitling them to substantial exemption. These qualifications are usually either the Higher National Certificate in Applied Physics or a university degree listed in schedule B (iii) of the membership regulations and including the General degree of the University of London at pass standard and Ordinary degrees of other universities. Holders of the university degrees referred to are normally required to take only More Advanced Physics and one other paper chosen by the candidate from the applied physics options, Mathematical Physics or Statistics. Up to and including the Graduateship Examination of this year the holders of the Higher National Certificate in Applied Physics have been granted exemption from all papers except two in Pure Physics. Beginning with the Certificate examinations of 1955, however, only candidates reaching a "credit" standard in all the papers of the Certificate examination are granted this measure of exemption and in future years many holders of the Certificate will be required to take additional papers. The General paper is taken by candidates who do not have examination evidence of general education.

About eighty candidates had been accepted for the 1955 examination, but, as usual, a substantial number requested transfer to a later

examination. Of the fifty-four candidates who took the examination several failed to attend for their second paper. Papers set in the examination are reproduced in this issue of the *Bulletin*.

The following is an analysis of the results according to the academic status of the candidates :—

	No. of candidates	Passes
(a) <i>Candidates required to take only two papers—</i>		
Holders of a degree (London General degree at pass standard, Ordinary degrees, etc.)	12	2
Holders of the Higher National Certificate in Applied Physics	35	9
(b) <i>Other candidates</i>	7	0

The results in each paper are :—

	No. of candidates	Passes
Physics I (General Physics and Acoustics) ...	40	17
Physics II (Heat and Optics)	33	10
Physics III (Electricity and Magnetism) ...	11	2
Mathematics I	5	2
Mathematics II	5	1
Mathematical Physics	3	0
More Advanced Physics	13	5
Electronics	11	3
High Vacuum Technology	4	1
X-rays	1	0
Practical Examination	6	5
General Paper	8	2

The following are comments by the examiners on the performance of candidates on the various papers :—

PURE PHYSICS I (General Physics and Acoustics)—Professor J. C. Wilson

Of 40 candidates, 15 attempted six questions, 16 attempted five questions, 7 four, 1 three and 1 two. The questions most frequently attempted were No. 6 (37 answers), No. 4 (31 answers) and No. 9 (28 answers); fewest candidates attempted No. 3 (10 answers).

In Section B, only four candidates out of forty failed to attempt two questions as instructed in the rubric; in Section A, on the other hand, twenty-two candidates did not answer the full number of questions (four). On the whole, marks for questions in Section B were appreciably higher than those for questions in Section A, and it seems likely that the questions in Section B followed more closely the form in which the

material is usually learned than did those in Section A, while the extent of the syllabus is probably proportionally smaller.

Answers to questions 1, 2 and 3 were generally very poor, nearly half the answers to question 4 were also very poor, answers to questions 5 and 6 showed a fairly normal performance while those to the questions in Section B were moderately good.

The use of language was, on the whole, encouraging, but the phrase "due to" was misused sooner or later by very many candidates.

Individual questions :

- Question 1. Answers were most disappointing, candidates being frequently diverted to kindred topics—viscosity of liquids, temperature variation of viscosity, etc. Few introduced the concept of mean free path with any clarity.
- Question 2. Two candidates visualized very clearly the characteristic features of this particular exercise, but even these did not appreciate the difficulties of measuring a diameter of about forty microns. Most of the remainder described a procedure suitable for piano wire (some even referred to the fibre as "the wire"), and several provided a derivation of the torsion formula, which was not required, and were left with no time to answer the question.
- Question 3. The answers were horrifying. Of ten candidates attempting the question, eight, without any reasoning to justify the procedure, took, for the most probable value of the quantity under discussion, a straight mean of the six values quoted. The uncertainty of this most probable value was rarely given as less than 500 km/s. Only one man realized that a comment, in words, as to the attitude he would adopt to the data presented, is a necessary preliminary to an adequate answer.
- Question 4. No candidate estimated quantitatively the difference between mean density and surface density necessary to account for the observed effect, but several candidates answered correctly in a qualitative manner. At least ten candidates, however, gave answers indicating that they supposed g to increase indefinitely towards the centre of the earth.
- Question 5. The general ideas of this question were understood, although not always well expressed.
- Question 6. This question was fairly well done, although there was a tendency for candidates to read "describe" for "discuss."
- Question 7. Candidates in general were either able to obtain an expression for the velocity of sound or knew in advance that they could not do so. The detailed questions (c) and (e) produced some good answers.

Question 8. Of answers to the Acoustics questions, the first part of this question was by far the most disappointing, (a) because "quality" was misunderstood by some candidates (e.g. quality is a property held in greatest measure by a pure sine wave), and (b) because candidates would not answer the question as it refers to a waveform in air. In the second part, effects connected with the acoustic properties of the hall were well treated, but no candidate referred to the polar diagram of the instrument.

Question 9. This question was, on the whole, well done.

PURE PHYSICS II (Heat and Optics)—Professor F. A. Vick

1. *General.* Many candidates were obviously quite inadequately prepared for this paper. Eight were awarded 20 per cent or less. It is true that some of the questions might have been set in the G.C.E. examinations, but a quite different standard of answer was expected. Of the thirty-three candidates only seven attempted six questions, though the other twenty-six were apparently not suffering from insufficient time.
2. *Heat (Section A).* Judging from the answers to question 1 a surprising number of candidates would measure the temperature of a room by hanging a constant-volume helium thermometer in it. Very few showed any appreciation of the use of radiation shields or any other precautions necessary to make this rather difficult measurement. Outstanding deficiencies in many of the answers to this section were the lack of evidence of a practical sense, of scientific judgement and of a knowledge of orders of magnitude. These attributes of a trained physicist are acquired largely by experience, of course, but at the standard of this examination some experience is expected.

Not many candidates tackled the very easy numerical example in question 2, and not all who did got full marks for it. Very few tackled question 3, which was one of the most difficult on the paper though on a very important topic. The misprint in question 4 (U for H in line 1) did not appear to cause difficulties to those who attempted the question. In answering question 5, few candidates appeared to have any idea of scale when drawing the energy distribution curves, though one or two did mention Wien's displacement law.

3. *Optics (Section B).* The standard of answers to this section was higher than for Section A, though question 6 was attempted by few and only one candidate did well. Most of the answers to question 9 were quite inadequate, but some candidates answered questions 7 and 8 very well.

PURE PHYSICS III (Electricity and Magnetism)—Professor F. A. Vick

The marks for this paper ranged from 4 to 72 per cent. A few of the candidates did lamentably badly and obviously had no idea of the standard of the examination. On the whole the calculations were either not attempted or badly done. The answers to Section B were poorer than those for Section A.

MORE ADVANCED PHYSICS—Professor J. G. Wilson

Of twelve candidates handing in scripts, eight attempted five questions, three attempted four and one attempted three. All questions but No. 5 (two answers) and No. 7 (one answer) were answered by from seven to ten candidates.

Question 1. This question was not well answered. Of ten candidates, two reached the correct answer to the first part, both inelegantly, while two candidates (not the same men) showed some understanding of the second part. Momentum gave unexpected trouble, for two candidates gave the momentum of a γ -ray quantum as hc/v , and two that of an electron as $\frac{1}{2}mv^2$.

Question 2. Answers ranged from one which was excellent to several extremely bad ones.

Question 3. All but one of the candidates attempting this question seemed familiar with the relationship between resolving power and wave length. Answers to the second part were poor.

Question 4. Answers to the first part were almost all of a superficial character. In the second (numerical) part, two candidates made no progress, three obtained answers which were more or less correct, three obtained answers which were manifestly absurd and one an answer which although very wrong was not absurd at sight.

Question 5. Both candidates attempting this question were satisfied with a resolving power of 50,000.

Question 6. Most of the answers showed understanding of the operation of an expansion chamber, but the diffusion chamber was almost unknown. The second part of the question was answered poorly and in a confused way by the majority of candidates.

Question 7. The only answer was largely irrelevant.

Question 8.—Answers to this question were by far the best on the whole paper. The subject appears explicitly in the syllabus for the paper, and candidates had probably "spotted" this question or something very like it.

The most striking general feature of the scripts is the difficulty experienced by most candidates in selecting from the knowledge they

have that which is relevant to answer the question. Irrelevant additions in this small group of scripts included :

- (i) a discussion of cascade showers in question 1,
- (ii) a discussion of optical resolving power in question 3 so extensive that electron optics was mentioned for the first time in the last five lines of a fairly long answer,
- (iii) an account of fission in question 4,
- (iv) a description of the bubble chamber in question 6, and an account of the applications of counter control, and
- (v) half of the only answer to question 7 devoted to cooling by paramagnetic demagnetization.

MATHEMATICS—Dr. J. Topping

As there were only five candidates, of whom one passed, it is difficult to comment generally. But the mechanics questions were hardly attempted, and no candidate showed that he knew how to deal with the approximation to the root of an equation or to use parametric co-ordinates. Other weaknesses were in statistics, partial differentiation and the use of vectors.

MATHEMATICAL PHYSICS—Dr. J. Topping

There were three candidates and none passed. There was one satisfactory answer to each of the questions 1, 2 and 3, but the remaining questions were either not attempted or done very badly.

APPLIED PHYSICS—Mr. A. E. De Barr

The answers to the applied physics papers were disappointing and showed very little appreciation of physical principles. Candidates who could quote or even derive formulae were usually unable to explain them or to use them to answer the questions asked. The impression left is that candidates do not expect to have to think about their answers and are accustomed merely to reproduce text-book material. Questions designed to test the candidate's ability to make use of his knowledge are usually either avoided or answered with a largely irrelevant account of some related topic.

As in previous years a particularly disturbing feature of the results is the general unwillingness or inability of candidates to attempt numerical questions. Even when the candidate does attempt such a question and is able to write down the simple physical relations required, he is usually unable to perform the necessary arithmetic required to produce the correct answer in sensible units. In applied physics particularly this is a serious failing for it is of only limited value to know how a triode valve works if the user cannot calculate the value

of the cathode resistor required, or to understand the working of a vacuum pump but be unable to calculate the necessary pumping speed. It may be that future papers in this subject should be set in such a way that numerical questions cannot so easily be avoided.

Individual questions

There were insufficient candidates in X-rays and High-Vacuum Technology to warrant any general comment on individual questions.

ELECTRONICS—Mr. A. E. De Barr

Questions 2, 3, 4, 5 and 6 were those most frequently attempted, whilst questions 1 and 7 were attempted by only one candidate.

Question 2. Amongst the answers to the first part of the question there were references to all the relevant topics but no candidate produced anything like a complete answer. Only a small number of answers mentioned energy levels or work function.

The answers to the second part of the question were generally good; but out of nine candidates who attempted the numerical part, only one reached the correct answer. All started correctly from Richardson's equation but not one differentiated it and most got lost in logarithms in simple arithmetic.

Question 3. Whilst most of the answers to this question revealed some knowledge of the factors involved, the information was not clearly set out.

Question 4. This was the most popular question—and also that for which the average mark given was least. Most candidates merely stated the effects of feedback on impedance, etc., only one candidate attempting an explanation. The answer expected would have explained, e.g., that the effect of voltage feedback is to reduce the current drawn from the source and thus to increase the input impedance, and also to tend to keep input and output signals identical, thus reducing distortion.

Most, but not all, candidates found the gain of the amplifier without feedback but none was able to calculate the value of the cathode resistor required to reduce the gain.

Question 5. Most candidates showed only a rudimentary knowledge of the essential features of the different types of oscillator, and contented themselves with a description of one example of each kind.

Question 6. Few candidates were able to say anything of the mechanism of secondary emission and still fewer showed any appreciation of the difficulties likely to be involved in measuring this property.

Question 8. Only two candidates attempted this question but they had no idea how to answer the numerical portion.

Question 9. Several quite good answers were received. The chief criticism is that candidates described or mentioned the origins of the various types of noise but did not discuss the nature of the effects in amplifiers, etc.

GENERAL PAPER—Mr. N. Clarke

The two candidates who passed reached a good standard. In one respect, ability to spell, even the failures showed a marked improvement upon the candidates of previous years.

The age of the youngest candidate was twenty-six years and that of the oldest forty years. Most of them lacked any ability to express themselves in simple straightforward English and betrayed an astonishing ignorance of questions that might be expected to impinge on their everyday experience.

Question 1 was fairly well answered. As in previous years, most candidates found it easier to express someone else's opinions than to think for themselves on even simple issues.

One of the candidates who failed the examination wrote a very good answer to this question. Two candidates, however, were clearly unable to understand the passage set.

Question 2 was attempted by all, but only three candidates had anything to say.

Question 3 was also answered by all the candidates, but there were only two worthwhile attempts.

Five candidates attempted question 4, but only one of them with any success.

No one answered question 5 (despite the controversy in the press over Mrs. Knight's broadcasts).

At question 6 there were three attempts. One of these was quite well done (by a candidate educated mainly in the United States!).

Three pathetic attempts were made to answer the question on careers open to physicists, but no one answered question 8.

PRACTICAL PHYSICS—Mr. A. E. De Barr and Mr. J. Yarwood

Candidates taking Practical Physics were required to perform two experiments. The first of these—the use either of a potentiometer to calibrate an ammeter, or of a spectrometer to determine the dispersive power of the material of a prism—was intended as a test of ability to make straightforward measurements with simple apparatus and to write an intelligent account of an experiment. No assistance was given and

whilst most candidates succeeded in making the measurements, few showed any signs of real familiarity with the simple equipment involved which a physicist should surely be able to handle with the same facility as a plumber uses a blow-lamp or a joiner uses a plane. The written accounts of the experiments were generally poor and incomplete. For instance no candidate made any estimate of the accuracy of his determination.

For the second experiment, candidates were required to perform a more elaborate experiment using apparatus which they had probably not previously seen. Most candidates were able, with assistance, to complete the experiment but most of them were unable to think out the correct experimental procedure or to plan the experiment properly.

PAPERS SET IN THE GRADUATESHIP EXAMINATION, 1955**PURE PHYSICS I—General Physics and Acoustics***Examiner : PROFESSOR J. G. WILSON, M.A., PH.D., F.INST.P.**MONDAY, 20th June—9.30 a.m. to 12.30 p.m.**(Answer SIX questions, FOUR from Section A and TWO from Section B.)***SECTION A**

1. Describe an experiment to demonstrate that the viscosity of a gas is independent of pressure.

Explain the bearing of this result on the concepts of the kinetic theory of gases.

2. You are required to determine the modulus of rigidity (about 3×10^{11} dyn./cm²) of quartz in the form of fibres 10 cm long and of diameter about 40 microns.

Outline an experimental procedure, indicating values for the dimensions of subsidiary equipment and for the performance of measuring instruments employed. What will limit the accuracy of the determination ?

(The breaking tensile stress for quartz is about 10^{10} dyn./cm²).

3. Six determinations of the velocity of light (in km/s) are quoted by their several authors with probable errors as follows :

298,000 $\pm$ 1,000 ; 298,500 $\pm$ 1,000 ; 299,930 $\pm$ 100 ;
299,900 $\pm$ 200 ; 300,100 $\pm$ 1,000 ; 299,994 $\pm$ 50.

(a) What would you adopt, from these figures, as the most probable value of the velocity, and what uncertainty would you assign to this value ?

(b) Are any of the determinations inconsistent with your conclusions ?

4. Show the relationship between the gravitational acceleration, g , and the constant of gravitation, G .

The acceleration, g , is measured at the surface of the earth and then in a deep mine, and is found to be greater in the mine than it is at the surface of the earth. Discuss this observation.

5. Explain what is meant by the group velocity of a wave motion, and show when and how it will differ from the phase velocity. Illustrate your answer by reference to the propagation of gravity waves over deep water.

6. Give an elementary account of the origin of the forces of surface tension.

Discuss methods for determining the surface tension of a clean water surface, bringing out the relative advantages and difficulties of the methods you propose.

SECTION B

7. Obtain an expression for the velocity of sound in a gas, and show briefly how (if at all) you would expect the velocity of sound in air to depend upon (a) the temperature, (b) the pressure, (c) the humidity of the air, and upon (d) the frequency and (e) the intensity of the sound wave.

8. What do you understand by the quality of a musical note, and what features would characterize this property in the wave-form of a sound in air?

Would you expect the quality of a note played upon a violin to be the same for listeners in different parts of a concert hall? Explain your conclusion.

9. Explain clearly why the structure of modern blocks of flats or offices may cause excessive transmission of sound. What principles must be adopted to secure good acoustic insulation for the rooms in such a building? How is this achieved?

PURE PHYSICS II—Heat and Optics

Examiner : PROFESSOR F. A. VICK, O.B.E., PH.D., F.INST.P.

MONDAY, 20th June—2.00 p.m. to 5.00 p.m.

(Answer SIX questions, at least TWO from each section)

SECTION A

1. Describe carefully how you would measure the temperature of :—

- (a) the air in a room ;
- (b) a molten alloy in a furnace at about $1,600^{\circ}\text{C}$;
- (c) a piece of metal at about -200°C .

2. Describe in detail how you would measure the coefficient of expansion of a crystal in a direction perpendicular to one of the faces.

If the coefficients of expansion of a crystal in three principal directions are 7.2×10^{-6} , 13.5×10^{-6} and 13.5×10^{-6} per deg. C respectively, calculate the coefficient of cubical expansion. Indicate how you would verify this experimentally.

3. Discuss the main methods available for the measurement of small quantities of heat.

4. Define Helmholtz Free Energy, F , and Enthalpy U .*

$$\text{Show that } U = F - T \left(\frac{\partial F}{\partial T} \right)_v$$

* Printing error, U for H .

The total heat of reaction corresponding to the liberation of one faraday of charge in a certain reversible voltaic cell (univalent electrode) is 8410 calories. If the temperature coefficient of e.m.f. is -2.5×10^{-3} volts/deg.C, calculate the e.m.f. of the cell at 17°C . What assumptions have you made?

(1 faraday = 96,500 coulombs).

5. Show that the energy density of radiation inside an enclosure at absolute temperature T depends only on T .

Sketch on the same diagram the distribution of energy with wavelength for a full radiator at (a) about 800°C , (b) about $2,000^\circ\text{C}$.

Discuss briefly the properties and uses of infra-red radiation.

SECTION B

6. Discuss the brightness of the image produced by a lens system.

Specify the characteristics of the lens or lens system you would use for each of the following purposes:—

- (a) as an eyepiece in a prism spectrometer for visible light;
- (b) in a camera for the photography of transient curves on a cathode-ray tube screen;
- (c) as the objective for the telescope of a theodolite.

7. Distinguish between Fresnel and Fraunhofer diffraction.

Indicate how diffraction may set a limit to the resolving power of an optical system.

The headlamps of a distant approaching car are 100 cm apart. At what distance will they be just resolved by the eye if the pupil diameter is 3 mm? Assume a wavelength of $5,555 \text{ \AA}$ and that the resolving power of the eye is determined by diffraction.

8. Describe a simple experiment to demonstrate that light has the properties of transverse wave motion.

Calculate the minimum thickness of a plate of doubly-refracting material to produce a phase change of π between the emergent O and E rays ($\lambda = 5,890 \text{ \AA}$, $\mu_E = 1.5530$, $\mu_O = 1.5439$). In what direction must the plate be cut? How must it be placed if the transmitted light is to be plane-polarized at right angles to the incident light?

How would you detect circularly polarized light?

9. Write a short essay on modern methods of spectroscopy and their applications.

PURE PHYSICS III—Electricity and Magnetism

Examiner : PROFESSOR F. A. VICK, O.B.E., PH.D., F.INST.P.

THURSDAY, 23rd June—9.30 a.m. to 12.30 p.m.

(Attempt SIX questions, not less than TWO from each section).

SECTION A

1. State Gauss's theorem in electrostatics.

A condenser consists of 10 parallel aluminium plates, each 10×15 cm, 1 cm apart. Alternate plates are connected together electrically. Between each pair of plates a sheet of plastic of thickness 6 mm and dielectric constant 7.2 is inserted and the whole system is then immersed in oil of dielectric constant 4.6. Calculate the capacitance of the condenser in microfarads. Derive any formula used.

2. Distinguish between diamagnetic, paramagnetic and ferromagnetic materials.

Sketch a hysteresis loop for a soft magnetic material subjected to a wide range of magnetizing force, H . With the aid of the diagram define *remanence* and *coercivity*. Also define *incremental permeability*. Discuss the importance of these three quantities in practice. Describe how you would determine experimentally the coercivity and remanence for a silicon-iron alloy.

3. Define self inductance, mutual inductance.

A laboratory standard mutual inductance consists of a primary coil wound uniformly with 2,500 turns on a length 120 cm of a cylinder 2 cm radius with a secondary coil placed centrally over the primary, 10 cm long and with 200 turns. Calculate (a) the self inductance of the primary, (b) the mutual inductance, (c) the stored energy when a current of 10 amp flows through the primary. Derive any formulae used, and give numerical results in practical units.

Indicate how a ballistic galvanometer may be calibrated with the aid of a standard mutual inductance.

4. Give the essential features of the instruments you would use for the following measurements :—

- (1) a current of the order of milliamperes at 100 kc/s. ;
- (2) a current of the order of 300 amp at 50 c/s. ;
- (3) a capacitance of the order of $100 \mu\text{F}$.

SECTION B

5. Explain carefully the purposes and properties of the second and third grids in a pentode valve.

How would you use a pentode valve or valves

- (a) in an amplifier stage?
- (b) in a push-pull output stage?

In each case draw a typical circuit showing the use of the valve, and indicate the characteristics required of the valve and the circuit.

6. Discuss briefly the evidence for the view that a neutral atom has a small positively-charged nucleus surrounded by a definite number of electrons.

Using the Bohr theory, calculate the radius of the normal orbit of the electron in a hydrogen atom.

$$(h = 6.61 \times 10^{-27} \text{ erg. sec.}, e = 4.77 \times 10^{-10} \text{ e.s.u.}, m = 9.10 \times 10^{-28} \text{ g.})$$

7. Give a critical account of the methods used to determine Planck's constant, h .

8. Explain how it was established that the rate of decay of a radioactive substance at any instant is proportional to the amount remaining at that instant.

How would you measure this rate of decay ?

Discuss briefly methods for determining half-value periods of radioactive decay, with special reference to very short and very long periods.

9. Give an account of the main methods for detecting ionizing particles.

MATHEMATICAL PHYSICS

Examiner : J. TOPPING, M.Sc., Ph.D., F.Inst.P.

TUESDAY, 21st June—2.00 to 5.00 p.m.

(Answer FOUR questions)

1. Derive Lagrange's equations for a dynamical system with two degrees of freedom.

A uniform rod of mass $2m$ and length l can turn freely about one end which is fixed ; to the other end is smoothly hinged another uniform rod of mass m and length $2l$. The system makes small oscillations in a vertical plane about the position of equilibrium. Find the two principal modes of oscillation and their periods.

2. Derive the equation of longitudinal elastic vibration of a uniform rod.

A uniform straight rod of length l , density ρ and Young's modulus E is clamped rigidly at both ends. Find the periods of the normal modes of longitudinal vibration. If the rod is strained initially so that the longitudinal displacement of any cross-section at a distance x from one end is given by $X = ax(l - x)$ where a is small, and is then released from rest, find the displacement of this cross-section at any subsequent instant.

3. Show that the temperature θ at time t at any point (x, y) of a uniform conducting lamina satisfies the equation

$$\frac{\partial \theta}{\partial t} = k \left(\frac{\partial^2 \theta}{\partial x^2} + \frac{\partial^2 \theta}{\partial y^2} \right)$$

radiation being neglected.

A uniform lamina in the form of a square has three of its sides maintained at 0°C , and the fourth at the constant temperature $T^\circ\text{C}$. Find the *steady* temperature of any point of the lamina.

4. Obtain the conditions that the electrostatic potential must satisfy at the common surface of two dielectrics.

A particle with charge q is situated in air at a distance d from the infinite plane boundary of a medium of dielectric constant K . Show that the particle is subject to a force, directed towards the boundary, of amount $(K-1)q^2/4(K+1)d^2$. Sketch the lines of force of the fields in and outside the medium.

5. Prove that the magnetic field at external points due to a uniformly magnetized sphere is the same as that of a magnetic dipole placed at the centre.

If the sphere is enclosed by a concentric spherical shell of soft iron of permeability μ , prove that the field at points external to the shell is reduced in the ratio

$$9\mu : 9\mu + 2(1 - a^3/b^3)(\mu - 1)^2$$

where a is the radius of the sphere, and a, b the radii of the shell.

6. Define the equivalent magnetic shell of a closed linear conductor carrying a steady current, and indicate the experimental results on which the definition is based.

Assuming that the magnetic vector-potential at any point P due to a uniformly magnetized shell of strength Φ is given by

$$A = \Phi \int ds/r$$

where the integral is taken round the boundary of the shell, and r is the distance of the elements ds from P , derive the value of the magnetic intensity at any point due to a system of current circuits.

Apply this result to find the magnetic intensity due to a steady current flowing in a long straight wire.

7. Plane electromagnetic waves, passing through a medium of dielectric constant K_1 , are incident on the plane boundary of another medium of dielectric constant K_2 and are polarized in the plane of incidence. Assuming that the permeability of each medium is unity, show that the amplitudes of the electric vector in the incident, reflected and refracted waves are in the ratio

$$\sin(\theta_1 + \theta_2) : \sin(\theta_2 - \theta_1) : 2 \sin \theta_2 \cos \theta_1$$

where θ_1 , and θ_2 are the angles of incidence and refraction respectively.

Show how this result explains that when light is reflected at the boundary of a denser medium there is a phase-change of π .

8. Certain wave-functions $\Psi(r)$ for the hydrogen atom are such that $F(r) = r\Psi(r)$ satisfies the equation

$$\frac{d^2F}{dr^2} + \frac{8\pi^2m}{h^2} \left(E + \frac{e^2}{r} \right) F = 0$$

Find solutions of this equation of the form $e^{-ar} f(r)$ where $a^2 = -8\pi^2mE/h^2$ and $f(r)$ is a series of ascending powers of r .

Show that the condition that Ψ tends to zero as r tends to infinity leads to the Bohr energy values $E = -2\pi^2me^4/h^2n^2$ where n is an integer.

9. Explain what is meant by the aberration of light.

Show how the observations may be accounted for using (a) Newtonian mechanics, and (b) the special theory of relativity.

MORE ADVANCED PHYSICS

Examiner: PROFESSOR J. G. WILSON, M.A., PH.D., F.INST.P.

TUESDAY, 21st June—9.30 a.m. to 12.30 p.m.

(Answer FIVE questions)

1. Obtain an expression for the energy of γ -ray quanta scattered through 90° by free electrons, and comment upon the result.

Over what range of energies of incident quanta is Compton scattering an important mechanism for the absorption of radiation?

2. Indicate briefly what is now understood about the condition of electrons in the solid state of matter. Illustrate your answer by reference, among other features, to the temperature variation of electrical conductivity in metals and in semiconductors.

3. What advantage is sought in the use of an electron microscope in place of an optical microscope, and upon what considerations is this expectation based?

Indicate some difficulties and limitations of electron microscopy.

4. Explain how conditions in the central zones of the sun may be expected to be suitable for the maintenance of thermonuclear reactions.

Assuming the energy output of the sun to arise from the synthesis of helium, and that solar energy reaches the earth (distant 1.5×10^{11} m) in a flux of 0.15 w/cm², determine at what rate hydrogen in the sun must be consumed.

$$(H = 1.00812; He = 4.00390).$$

5. Survey the techniques available for achieving high resolution in spectroscopic observations.

Determine the resolving power required for investigating the distribution of intensity across a spectral line of wavelength $5,000$ Å

and half-width $0.1 \text{ \AA}$, and indicate (considering dimensions) how this would be realized.

6. Describe the operation of the expansion chamber and of the diffusion cloud chamber, and explain what information about a fast charged particle may be obtained from the study of a cloud track which it has formed.

7. Describe and discuss the magnetic properties of metals at temperatures below 10°K .

Indicate briefly how the relevant measurements are made.

8. What were the considerations which prompted the performance of the Michelson-Morley experiment? Describe this experiment, and discuss the conclusions which may be drawn from its results.

ELECTRONICS

Examiner : A. E. DE BARR, B.Sc., F.Inst.P.

TUESDAY, 21st June—2.00 to 5.00 p.m.

(Answer FIVE questions)

1. Describe the principles of beam focusing in a cathode-ray tube by (a) magnetic, (b) electric fields, and make a critical comparison of the two methods.

The cylindrical anode and cathode of a magnetron are 32mm and 22mm diameter respectively. Calculate the potential difference required between anode and cathode in order that electrons may circle the cathode, mid-way between cathode and anode, at 2.5×10^8 revolutions per second. The magnetic flux density parallel to the axis of the electrodes is 1300 gauss.

2. Explain what is meant by thermionic emission and describe how you would investigate its variation with temperature for a particular surface.

Explain briefly why, although the three common types of thermionic cathode have widely different emission efficiencies, all three are nevertheless in general commercial use.

By how many electron-volts must the work function of a surface change in order to reduce the emission from that surface at $2,400^\circ\text{C}$ by 10%?

3. Describe the action of a triode valve and explain how the properties of the materials with which it is made, and the size and spacing of the electrodes, determine (a) the maximum current and voltage which can be handled, (b) the highest frequency signal which can usefully be

handled, (c) the maximum voltage and power amplifications, (d) the useful life of the valve.

Describe briefly how you would determine the anode characteristics of a pentode valve.

4. Explain *in words* the effects of current and voltage negative feedback in any system for the amplification of electrical signals. Refer particularly to (a) input and output impedance, (b) frequency response, (c) distortion.

In a single-valve pentode amplifier the load resistance is 65,000 ohm, $g_m = 1.75 \text{ mA/volt}$, the impedance of the valve is 0.95 megohm, and the anode current is 3.15 mA. Draw the equivalent a.c. circuit and from it deduce the gain of the amplifier. Calculate the values of (a) the cathode resistor necessary to reduce the gain to 25, (b) the bias resistor required for a grid bias of -2.2 volt. Sketch the complete circuit and indicate suitable values for the components in the grid and cathode portion of the circuit.

5. Describe briefly the differences between regenerative, negative resistance, and relaxation oscillators.

Give circuit diagrams for, and explain the action of oscillator circuits for producing (a) accurately sinusoidal signals of a fixed frequency at about 500 kc/s, (b) square waves of about 200 c/s, (c) saw-tooth waves of about 10 kc/s, (d) a train of rectangular pulses at a pulse repetition rate of about 10^6 per second.

Indicate possible applications for each type of oscillator.

6. Explain what is meant by "secondary emission" and describe how you would measure the secondary emission properties of a surface.

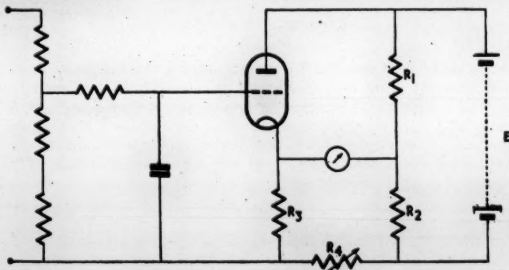
Discuss the importance of secondary emission in (a) triodes and pentodes, (b) cathode-ray tubes, (c) photomultiplier tubes.

7. Discuss the effects of gas in electron tubes, referring particularly to its effect on the voltage-current characteristics of (a) gas-filled photoelectric cells, (b) Geiger-Müller counters, (c) gas-filled thermionic diodes.

Consider electrons moving from anode to cathode in a discharge tube containing argon at a low pressure. The separation of anode and cathode is 2 cm. What fraction of the electrons leaving the cathode will probably collide with at least one argon atom before reaching the anode if the pressure in the gas is (a) 10^{-7} mm of mercury, (b) 10^{-2} mm of mercury?

(Assume the mean free path for electrons to be 5.66 times that for gas molecules).

8. The diagram shows the circuit of a d.c. valve voltmeter. Describe the manner of operation of the circuit and explain the function of each component. What are the disadvantages of this type of circuit for this purpose?



$E = 100$ volt, $R_1 = 6500$ ohm, $R_2 = 3500$ ohm, $R_3 = 500$ ohm, $R_4 = 9500$ ohm.

Meter resistance 300 ohm. Valve $\mu = 19$, $g_m = 2.1$ mA/volt.

Find (a) the anode current when the meter reads zero, (b) the d.c. input required to produce a current of 1 mA through the meter.

9. Write an account of the origin and nature of the different kinds of electrical "noise" which limit the performance of electronic devices.

Electronic charge, e

$1.602 \cdot 10^{-19}$ coulomb

Electronic mass, m

$9.107 \cdot 10^{-28}$ gram

Boltzmann's constant, k

$1.38 \cdot 10^{-23}$ joule/deg. K

Mean free path of argon molecules at N.T.P.

$6.3 \cdot 10^{-6}$ cm.

ACOUSTICS

Examiner : A. E. DE BARR, B.Sc., F.INST.P.

TUESDAY, 21st June—2.00 to 5.00 p.m.

(Answer FIVE questions)

1. A mass is supported by a light spring from a fixed base and executes forced vibrations under the influence of an applied periodic force, the motion being damped by a force proportional to the velocity of the mass. Derive an expression for the ratio of the force transmitted to the base to the applied force, and sketch curves to illustrate how this ratio varies with the frequency of the applied force and with the damping.

If, when the mass is at rest, the extension of the spring is 1 cm, what is the ratio of the applied force to that transmitted to the base if the frequency of the applied force is 15 c/s and the damping is (a) small, (b) critical ?

Discuss briefly the design of mountings for insulating a sensitive galvanometer from structure-borne disturbances.

2. Discuss the propagation of plane waves in a viscous fluid contained within a rigid tube of circular cross-section.

If such a tube contains water and is transmitting vibrations at 100 c/s, what must be the minimum radius of the tube if the attenuation due to viscous damping is not to exceed 1 decibel per metre ?

3. Derive an expression for the acoustical impedance at the surface of a spherical source, and explain how it varies with the frequency of the source.

The r.m.s. velocity at a point 10 cm from a small source in free air is 0.3 cm/sec. If the frequency of the source is 1,000 c/s, what is the strength of the source and what is the rate of radiation of sound energy ? How is the rate of radiation of energy affected if a reflecting baffle is placed 5 cm from the source ?

Explain this result briefly.

4. Explain the physical reasons for (a) the necessity of reflection at a change in area of a conduit along which sound waves are propagated, (b) the increase of acoustical output of a wind instrument by the use of a resonating air space.

Explain also how and why the design of an exponential horn for a loudspeaker differs from that of a horn for a brass wind instrument.

5. Describe the procedure you would adopt for the absolute free-field calibration of a microphone using (a) a method involving the measurement of the velocity amplitude at a point in space, (b) the reciprocity technique.

What factors limit the accuracy attainable by each method ?

6. Describe the action and properties of (a) porous, (b) panel, (c) resonant surfaces for use as acoustical control surfaces. Discuss the advantages and application of each type.

The reverberation time of a room 30 feet by 20 feet by 15 feet is 3 seconds. 250 square feet of the surface are then coated with an absorbent material and the reverberation time is reduced to 2 seconds. What is the absorption coefficient of the coating, and what area of the surface of the room would have to be coated in order to reduce the reverberation time to 1.5 seconds ?

7. Describe how you would measure the variation of the velocity of sound in moist air with the partial pressure of water vapour in the air.

Discuss the effects of wind, temperature and water vapour on the wave front of sound from a source near to the ground.

8. Discuss the effects of interference of sound waves in connection with the directional properties of microphones and loudspeakers. Give examples of ways in which the directional properties may be accentuated or minimized and indicate some applications of these methods.

How would you measure the directional properties of a loudspeaker ?

9. Discuss the problems involved in the high-fidelity reproduction of sound by a system consisting of microphone, amplifier, and loudspeaker.

Physical properties at N.T.P.

	<i>Velocity of sound</i>	<i>Density</i>	<i>Viscosity</i>
	cm/sec	g/cm	poise
Air	$3.4 \cdot 10^4$	$1.29 \cdot 10^{-3}$	$1.81 \cdot 10^{-4}$
Water	$1.4 \cdot 10^5$	1	$1.80 \cdot 10^{-2}$

HIGH VACUUM TECHNOLOGY

Examiner : A. E. DE BARR, B.Sc., F.INST.P.

TUESDAY, 21st June—2.00 to 5.00 p.m.

(Answer FIVE questions)

1. Describe the mechanism of the heat loss from a hot wire by conduction through a gas when the mean free path of the gas molecules is large compared with the diameter of the wire.

If it is desired to admit gas into a vacuum system in order to cool rapidly a hot object, what is the most suitable gas to use, and at what pressure ?

Describe briefly the construction and properties of a gauge for the measurement of low pressures which depends for its action on the heat loss from a hot wire.

2. Discuss the flow of gas under the influence of a pressure gradient under conditions of (a) streamline flow, (b) turbulent flow, (c) molecular flow.

What are the effects on the rate of flow of bends or elbows in the system ?

How do the above considerations influence the design of high vacuum systems ?

Calculate Reynolds's number for the flow of air in the 2 cm diameter backing line of a large diffusion pump with a speed of 30,000 litre/sec, operating at a pressure of 10^{-3} mm of mercury.

3. Describe the construction and operation of a molecular pump, and compare its properties and characteristics with those of a diffusion pump operating under the same conditions. Indicate the factors which influence a choice between the two kinds of pump for various types of work.

A pump with a speed of 10,000 litre/sec is capable of evacuating a system to a pressure of 5×10^{-7} mm of mercury. The backing pressure must not exceed 10^{-3} mm of mercury. This pump is backed by a booster pump, the backing pressure of which must not exceed 10^{-1} mm of mercury, and a mechanical pump with a limiting pressure of 5×10^{-3} mm of mercury. If, due to evolution of gas within the system, the lowest pressure attainable is 10^{-4} mm of mercury, what must be the speeds of the booster and mechanical pumps to deal with the gas evolved ?

4. Discuss the relative merits of mercury and oil as the pumping fluid in a diffusion pump.

Explain how small quantities of the fluid can migrate into the high vacuum side of the system, and discuss briefly the design of baffles and traps to minimize this effect.

A pump is evacuating a system through a pipe with a conductance of 5 litre/sec. There is a small leak into the system and two identical ionization gauges, operating under identical conditions, are used to measure the pressure at each end of the pipe. If, when steady conditions are reached, the readings of these gauges are $2.4 \mu\text{A}$ and $4.5 \mu\text{A}$, what is the speed of the pump? If the volume of the system to be evacuated is 20 litre, how long will it take for the reading of the gauge at the end of the pipe remote from the pump to fall from $10 \mu\text{A}$ to $5.5 \mu\text{A}$?

5. Discuss the nature and significance of the "pressure" measured by the usual types of high vacuum gauge. (Hydrostatic pressure, thermal conductivity, viscosity, radiometer and ionization gauges).

Consider also the effects of the nature of the gas in the system and of temperature differences between gauge and the rest of the system.

6. Explain how and why the nature of a discharge between electrodes in a gas at reduced pressure enables an estimate to be made of the pressure in the gas.

In a mixture of two gases of molecular weights M_1 and M_2 , molecular diameters σ_1 and σ_2 , and partial pressures p_1 and p_2 , the mean free path for molecules of type 1 colliding with molecules of type 2 is given by

$$\lambda_{1,2} = \frac{4kT}{\pi p_2 (\sigma_1 + \sigma_2)^2 \left(1 + \frac{M_1}{M_2}\right)^{\frac{1}{2}}}$$

where k is Boltzmann's constant and T is the absolute temperature. Make use of this expression to calculate the mean free path of an electron in argon at a pressure of 10^{-3} mm of mercury.

7. Describe the construction and the manner of operation of a helium leak detector, and indicate the types of high vacuum system in which such a detector would be used. If one part of helium in 10^5 parts of air can just be detected with a mass spectrometer, and helium leaks into a vacuum system at twice the rate of air under the same conditions, estimate the size of the smallest detectable leak into a vacuum system at a pressure of 2×10^{-5} mm of mercury, pumped by a pump with a speed of 150 litre/sec.

8. How would you measure the vapour pressure of a gasket material over the temperature range from -200°C to 200°C ?

Discuss the relative merits of glass and metal vacuum systems for various industrial purposes and with particular reference to the techniques available for making joints and for the fitting of valves.

9. Write an account of the theory, practice and industrial applications of cathodic sputtering and the evaporation in vacuum of metals and non-metals.

<i>Physical Properties of Gases</i>				
	<i>Viscosity at 20°C</i>	<i>Mass of a molecule</i>	<i>Molecular Weight</i>	<i>Mean Free Path at N.T.P.</i>
	poise	g		cm.
Helium	$1.94 \cdot 10^{-4}$	$6.64 \cdot 10^{-24}$	4.0	$11.2 \cdot 10^{-6}$
Argon	$2.20 \cdot 10^{-4}$	$66.2 \cdot 10^{-24}$	39.9	$11.2 \cdot 10^{-6}$
Air	$1.80 \cdot 10^{-4}$	$47.8 \cdot 10^{-24}$	28.7	$3.9 \cdot 10^{-6}$
Boltzmann's constant, k			$1.381 \cdot 10^{-23}$	joule/deg. K
Density of mercury at N.T.P.				13.6 g/cm^3 .
Acceleration due to gravity				981 cm/s^2 .

X - RAYS

Examiner : A. E. DE BARR, B.Sc., F.INST.P.

TUESDAY, 21st June—2.00 to 5.00 p.m.

(Answer FIVE questions)

1. Explain how the waveforms of the intensity of the continuous and characteristic radiation from an X-ray tube vary as the peak voltage applied to the tube is increased. Consider (a) a self-rectifying circuit, and (b) a voltage-doubling circuit.

How would you arrange to examine these waveforms experimentally ?

2. Explain the existence of absorption edges and discuss the relation between the structure of the absorption edges of an element and its characteristic X-ray spectrum.

Calculate the thickness of a 50% by weight iron-nickel alloy, of density 8.25 g/cm^3 , required to reduce the ratio

Intensity of cobalt $K\beta$ radiation

Intensity of cobalt $K\alpha$ radiation

from 1 : 5 to 1 : 600.

3. Explain how the size of the focal spot on the target of an X-ray tube may be controlled and describe one system for producing a very small focal spot. What factors determine the minimum size of focal spot that can be used in a given X-ray tube ?

Describe briefly the effect of the size of the focal spot in either X-ray diffraction, or radiography.

4. Discuss the advantages and disadvantages of the various methods available for the detection and measurement of the quantity

of X-radiation. Refer particularly to (a) sensitivity, (b) accuracy, (c) the effect of the wavelength of the radiation.

In a given densitometer the deflection of the galvanometer is a linear function of the amount of light transmitted by the film, and a galvanometer deflection of 100 corresponds to an optical density of 0.1. Compare the intensities per unit area of two X-ray beams of the same wavelength which produce, in the same exposure time, blackening of the film such that the galvanometer deflections are 15 and 10 respectively when the films are placed in the densitometer. The galvanometer reading corresponding to the unexposed portions of the films is 70. Assume that the processing conditions have been chosen so that the density of the film varies linearly with the exposure.

5. Describe how you would investigate, and specify, the quality of a given beam of X-radiation. Explain how the dosage rate due to an X-ray beam of given intensity varies with the wavelength of the radiation.

If the mass absorption coefficient of air for a given beam of X-rays is $0.2 \text{ cm}^2/\text{g}$, what quantity of radiation is required over an area of 100 cm^2 to pass 1 joule of X-ray energy into the area?

6. Discuss the advantages and disadvantages of X-ray diffraction methods for the measurement of strains in solids. Describe briefly one X-ray diffraction technique for measuring strain in a given direction in the surface of an object.

It is desired to measure the strain in a sample of chromium plating, the radiations available being chromium $K\alpha$, manganese $K\alpha$, iron $K\alpha$ and cobalt $K\alpha$. Which reflection and which wavelength would you use in order to obtain the most accurate result?

7. Discuss the diffraction by a crystal of a slightly divergent beam of monochromatic X-radiation. Describe qualitatively the effects of (a) the size of the crystal, (b) the arrangement of the atoms in the crystal, (c) the nature of the atoms in the crystal, (d) the perfection of the crystal structure, on the intensity, position, and angular width of the diffracted beams.

8. Discuss the possible dangers to health in the use of X-ray equipment. Explain how these may be minimized by suitable design of the apparatus, and describe the precautions which should be taken to safeguard the health of the operators.

9. Write an account of the coherent and incoherent scattering of X-rays by matter, with particular reference to their variation with (a) the wavelength of the primary beam, (b) the direction of measurement of the scattered radiation, (c) the nature of the scattering medium.

Crystal Structure				
Element	Structure	Lattice constant— $\text{\AA}$		
Chromium	Body-centred cubic	2.879		
K Emission and Absorption Wavelengths— $\text{\AA}$				
Element	Atomic Number	Emission Line	Absorption	
		K α	K β Edge	
Chromium	24	2.285	2.066	
Manganese	25	2.098	1.892	
Iron	26	1.932	1.739	
Cobalt	27	1.785	1.617 1.604	
Nickel	28	1.655	1.484	
Copper	29	1.537	1.377	
Mass Absorption Coefficients cm^2/g				
Element	Density	Radiation		
	g/cm^3	Copper K α	Nickel K α	Iron K α Chromium K α
Iron	7.9	324	397	72.8 114
Nickel	8.9	49.2	61.0	93.1 145
Energy required to form one ion-electron pair in air				5.27×10^{-11} ergs.
Electronic charge, e				4.8×10^{-10} e.s.u.
Density of air at N.T.P.				1.293×10^{-3} g/cm^3

MATHEMATICS I

Examiner : J. TOPPING, M.Sc., Ph.D., F.INST.P.

WEDNESDAY, 22nd June—9.30 a.m. to 12.30 p.m.

(Answer SIX questions)

1. Show that $x^4 - 2x^3 + 1.5x^2 - 4.1$ is an increasing function of x for all positive values of x . Deduce that the equation

$$x^4 - 2x^3 + 1.5x^2 - 4.1 = 0$$

has only one positive real root, and find this root correct to three decimal places.

2. Sketch the graph of the curve given by $x = 4 \cos^3 \theta$, $y = 2 \sin^3 \theta$. Find the total length of the curve, and the shortest distance of any point on the curve from the origin.

3. Show that

$$\sinh(A+B) = \sinh A \cosh B + \cosh A \sinh B$$

and by differentiation, or otherwise, obtain the expansion of $\cosh (A+B)$.

If $\cosh (u+iv) = x+iy$, show that the curves $u=\text{constant}$ and $v=\text{constant}$ in the (x, y) plane cut orthogonally. Sketch these curves.

4. (a) Solve the equation

$$(x-y) dx + (x+y+2) dy = 0$$

- (b) Substitute $y=vx$ in the equation

$$x^2 \frac{d^2y}{dx^2} + 2x \frac{dy}{dx} - 2y = x^2 + 4$$

and solve the resulting equation.

5. If $f(x)$ can be represented over the range $-\pi < x < \pi$ by the Fourier Series

$$\frac{1}{2}a_0 + \sum_{r=1}^{\infty} (a_r \cos rx + b_r \sin rx)$$

find a_0 , a_r and b_r .

If $f(x)$ equals $-\pi$, $2x$, π over the ranges $(-\pi, -\frac{1}{2}\pi)$, $(-\frac{1}{2}\pi, \frac{1}{2}\pi)$ and $(\frac{1}{2}\pi, \pi)$ respectively, find the constants in the Fourier series.

Sketch the function which the Fourier series represents for all values of x .

6. A thin rectangular plate $OABC$ with $OA=a$ and $OC=b$ is such that the surface density at any point P equals kOP^2 . Find the mass of the plate, the position of its centre of mass and the moment of inertia of the plate about OB .

7. A straight rod AB moves in the (x, y) plane in such a way that the end A slides along the axis Ox and the rod touches the parabola $x^2=4ay$. If the length of the rod equals $8a$, find the greatest distance A can move along Ox .

Prove that the locus of the instantaneous centre of the motion of the rod, referred to the axes Ox and Oy , is another parabola. Find also the locus of the instantaneous centre referred to axes along and perpendicular to the rod.

8. Show that the equation of the path of a particle which moves subject to a central force of magnitude P per unit mass is given by

$$\frac{d^2u}{d\theta^2} + u = \frac{P}{h^2u^2}$$

where $u = 1/r$, and (r, θ) are polar co-ordinates. What is the physical significance of h ?

If $P = au^2 + bu^3$ where a and b are constants and b is small compared with h^2 , show that for certain initial conditions the path may be described as an ellipse of which the apse-line rotates about one focus.

9. A light string is stretched tightly between two points at a distance $4l$ apart, and a mass $2m$ is attached at the middle point of the string. Find the period of transverse vibrations of the mass.

If an additional mass m is attached to the string at a distance l from one end, find the normal modes of oscillation of the system and the ratio of the amplitudes of the two masses in each normal mode.

MATHEMATICS II

Examiner : J. TOPPING, M.Sc., Ph.D., F.INST.P.

WEDNESDAY, 22nd June—2.00 to 5.00 p.m.

(Answer SIX questions)

1. (a) If $y = a^2 / (a^2 + x^2)^{3/2}$ find the value of x for which the error in the calculated value of y is numerically greatest, assuming that the error in x is independent of x .

(b) The gravitational constant G is calculated from the formula

$$G = \frac{4\pi^2 I}{A_1 - A_2} \left(\frac{1}{T_1^2} - \frac{1}{T_2^2} \right)$$

where I, A_1, A_2 are constants, and T_1, T_2 are observed times of oscillation. Find the fractional error in G due to fractional errors f_1 and f_2 in T_1 and T_2 respectively.

2. If $y = e^{a \sin^{-1} x}$ prove that

$$(1 - x^2) \frac{d^2 y}{dx^2} - x \frac{dy}{dx} = a^2 y$$

Use Leibnitz's Theorem to obtain the expansion of y in ascending powers of x .

From this expansion deduce the expansion of $\sin^{-1} x$.

3. Define the mean and median of any set of quantities.

If an infinite population is distributed such that the frequency of any quantity x is given by $f = x^2(2 - x)$ over the range $0 \leq x \leq 2$, find the mean and median of the distributions.

4. If $\mathbf{a} \cdot \mathbf{b}$ denotes the scalar product of the vectors $\mathbf{a}$ and $\mathbf{b}$, which are functions of t , prove from first principles that

$$\frac{d}{dt}(\mathbf{a} \cdot \mathbf{b}) = \frac{d\mathbf{a}}{dt} \cdot \mathbf{b} + \mathbf{a} \cdot \frac{d\mathbf{b}}{dt}$$

A, B, C are three fixed points and P is a variable point; show that if $PA^2 + PB^2 + PC^2$ is a minimum P must be the centroid of the triangle ABC .

5. (a) Use the method of dimensions to show that the resistance F acting on a sphere of diameter d , moving with speed v through a fluid of density ρ and viscosity η , may be expressed in the form

$$F\rho\eta^{-2} = \varphi(\rho vd\eta^{-1})$$

Given that $\varphi(x) = ax + bx^2$, find F .

(b) A sphere falls from rest subject to a resistance proportional to its speed. Find the speed of the sphere at any instant and deduce its terminal speed.

6. (a) If the cartesian and polar co-ordinates of a point are connected by the relations $x = r \cos \theta$ and $y = r \sin \theta$ show that

$$\frac{\partial x}{\partial r} = \frac{\partial r}{\partial x} \quad \text{and} \quad \frac{\partial x}{\partial \theta} = r^2 \frac{\partial \theta}{\partial x}$$

(b) Show that the equation

$$\frac{\partial^2 V}{\partial r^2} + \frac{1}{r} \frac{\partial V}{\partial r} + \frac{1}{r^2} \frac{\partial^2 V}{\partial \theta^2} = 0$$

has solutions of the form $V = (Ar^n + Br^{-n}) f(\theta)$ where A, B and n are constants. Find the function $f(\theta)$.

Deduce a solution of the equation that vanishes when $r = a$, and tends to $Er \cos \theta$ when r is large.

7. (a) A spot of light moves in a plane such that its position at time t is given by $x = a \cos nt$, $y = b \sin(nt + \alpha)$ where a, b, n, α are constants. Describe its path.

Show that the position-vector $\mathbf{r}$ of the spot of light can be written as

$$\mathbf{r} = \mathbf{c} e^{int} + \mathbf{d} e^{-int}$$

Interpret this equation physically.

(b) The position of a particle at time t is given by $x = 4 \cos \pi t$, $y = 2 \sin(2\pi t + \frac{1}{2}\pi)$.

Sketch the path of the particle and find the area enclosed by it.

8. Show that the equation of a uniform chain hanging freely under gravity may be written as $y = c \cosh x/c$.

A uniform chain hangs over two smooth pegs at different levels ; there is a length l of chain between the pegs and lengths a and b hang vertically. Find the difference in height of the two pegs and the parameter c of the catenary formed by the hanging portion.

9. A disc of moment of inertia I is fixed on a shaft of small radius r . Round the shaft is wound a length l of thin chain of mass m per unit length, one end of which is fixed to the shaft while the other carries a mass equal to twice that of the whole length of chain. The system is released from rest with the attached mass level with the axis ; write down the energy equation at any instant.

Find the time taken for the whole length of chain to unwind.

GENERAL PAPER

Examiner : N. CLARKE, B.Sc., F.INST.P.

TUESDAY, 21st June—2.00 to 5.00 p.m.

(Answer questions 1 and 2 and any THREE others)

1. Give the substance of the following passage in your own words :

"This is the predicament of Western man. He has built up a complex civilization, but he may lose it because, in his proud hour of achievement, he has so largely lost or never developed the inner resources that are needed to keep a possible boon from becoming a calamity.

It is important to make it abundantly clear at this point that the crucial problem is the spiritual problem, and we here mean by spiritual that area which is the object of attention in philosophy and theology as against that area in which the object of attention is mechanical contrivance. The fact that our life is so gravely threatened in the brightest day of technical achievement is not a criticism of the engineers *qua* engineers, but it is a criticism of all of us as men. The paradox of failure at the moment of success is by no means a condemnation of technical progress, for such progress is morally neutral. It gives the surgeon's knife, and it gives the gangster's weapon. Our predicament is a commentary, not on instruments and instrument makers, but on the human inability to employ both scientific knowledge and technical achievement to bring about the good life and the good society. Man is an animal who is peculiarly in need of something to buttress and to guide his spiritual life. Without this, the very capacities that make him a little lower than the angels lead to his destruction. The beasts do not need a philosophy or a religion, but man does.

When we say that the most urgent problem of our time is the spiritual problem we are opposing directly the popular opinion. Most people do not believe it. It is curious to note the way in which our world calamity has destroyed some of our comfortable delusions, but not others. Thus we have been pretty well emancipated from the dogma of automatic progress and even from faith in the goodness of man. In these matters we have shown some ability to be taught by experience. But we have not been equally emancipated from the belief that economic and technical reconstruction are enough. We suppose, quite naively, that the problem of spiritual reconstruction will take care of itself or that it can be left to the experts as a departmental matter.

The lesson of our time is that this delusion is no better than any other delusion. The problem will not take care of itself. Unless the spiritual problem is solved, civilization will fail ; indeed, we already have a foretaste of that failure in many parts of the world. Man's sinful nature is such that he will use instruments of power for evil ends unless there is something to instruct him in their beneficent uses. Without the conscious and intelligent buttressing of what has been demonstrated as precious, human society goes down.

It ought to be clear to us that such a task is so amazingly difficult that we should employ our greatest single effort in this direction. If we had even the beginning of wisdom, we should encourage our brightest men and women to devote themselves to the task of spiritual reconstruction. We should put our best thought into the elaboration and promulgation of an adequate faith rather than into some new machine. If we could put the same keen intelligence and careful judgment into the revival of faith that we now put into the production of magnificent machines, man's life on this earth might come into a new and glorious day.

The chief weakness of modern Western man is weakness of the head rather than weakness of the heart. He is sympathetic and full of good aspirations ; he is mild and kind ; and he hates war. His strange delusion is the notion that the kind of world he seeks can be supported in mid-air, without a foundation."

D. ELTON TRUEBLOOD.

2. Write an essay on one of the following subjects :—

- Weather Forecasting
- Modern British Composers
- The United Nations Organization
- The Roads of Britain
- Racial Discrimination.

3. Local dialects and social customs are tending to disappear. What do you consider to be the reasons for this and how far do you think that such disappearance is desirable?

4. Discuss the arguments used in support of and in opposition to the introduction of sponsored television programmes. What is your opinion of the Government's decision on this matter?

5. What do you understand by *scientific humanism*? To what extent is it correctly described as "scientific"?

6. Discuss the present economic, political and social conditions in any one of the following colonies giving relevant historical and geographical details.

(a) Jamaica, (b) Gold Coast, (c) Cyprus, (d) Kenya.

7. Give an outline of a talk you might give to schoolboys on the careers nowadays open to physicists.

8. Discuss the work of any one of the following:—

Christopher Fry

T. S. Eliot

Graham Greene

Osbert Sitwell

Lloyd Douglas

PRACTICAL PHYSICS

Examiners: A. E. DE BARR, B.Sc., F.INST.P., and
J. YARWOOD, M.Sc., F.INST.P.

FRIDAY, 24th June

(TWO questions, selected by the Examiners, will be allotted to each candidate)

1. Calibrate the ammeter provided at a number of points on the scale.

2. Find the dispersive power of the glass of the prism provided, using light of the wavelengths indicated.

3. Determine the optical stress coefficient of a strip of celluloid using a Babinet compensator.

4. Calibrate a Pirani gauge over the range of pressures from 3×10^{-3} to 10^{-1} mm. Hg. approximately, using a McLeod gauge as a standard.

5. Obtain a speed-pressure characteristic for the mechanical rotary pump provided.

6. Determine the negative grid current characteristic for the thermionic valve provided. The recommended operating potentials are to be obtained from the valve catalogue.

7. A tetrode electrometer valve is provided together with the appropriate manufacturer's data. Set up a simple circuit to use this valve as a d.c. amplifier and determine the effective mutual conductance of the circuit.

8. Determine the latent heat of vaporization of liquid air.

9. A Rayleigh refractometer is provided. Determine the refractive index of air over the range from 0 - 20 cm. Hg.

10. Use a radio-frequency method to determine the dielectric constant of the oil provided.

11. Find the wavelength in carbon tetrachloride of a propagated wave of ultra-sound, using an optical diffraction method.

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The British Coal Utilization Research Association invites applications for the following vacancies which should be addressed to the Assistant Secretary, B.C.U.R.A., Randalls Road, Leatherhead:—

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Research Assistant required to work on problems of mechanical firing and automatic control of sectional boilers. The post is an opportunity for a keen man, interested in this type of research, to get experience with a highly instrumented installation which offers unique facilities for experimental work. Applicants should preferably have Inter B.Sc. in Physics or Engineering, but those with Matriculation in these subjects would be considered. Starting salary in range £400-£650. Ref. B.49.

Research Assistant required for interesting work on domestic heating in exceptionally well equipped laboratories. The post offers an opportunity for training in modern research techniques and experience of automatic control methods and instrumentation. Applicants should preferably have Inter B.Sc. in Physics, but those with Matriculation in Physics would be considered. Starting salary in range £400-£650. Ref. B.50.

Physicist required at Ministry of Supply London H.Q. to be responsible for development of Air Photographic equipment. Duties include preparation of contract proposals for research and development projects, scrutiny of specifications, supervision of work and assessment of results. Qualifications: 1st or 2nd class honours degree or equivalent in physics. Three years' postgraduate research experience preferably in physical optics, photoelectricity or photographic processes and some knowledge of electronic equipment may be an advantage. Appointment as **Senior Scientific Officer** (min. age 26) £1,070-£1,245 (Superannuable). Equal pay scheme. Application forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A.325/5A. Closing date October 29, 1955.

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Applications, together with the names of two referees, should be addressed to the undersigned so as to reach him not later than November 1, 1955.

G. R. Hanson,
Registrar of King's College.

X-ray Crystallographer required for the Shepherds Bush Research Laboratories of **British Insulated Callender's Cables Ltd.**, for investigation into metallic corrosion problems, alloy structures, ferro-electric and ferro-magnetic materials. Candidates should be graduates and some previous research experience is desirable. Pension Fund. Five day week. Applications giving details of age, qualifications and experience should be made in the first instance to Staff Officer, B.I.C.C. Ltd., 21 Bloomsbury Street, London, W.C.1., quoting reference number L/13/55.

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